MEMORANDUM

AN INTRODUCTION TO THE NARM

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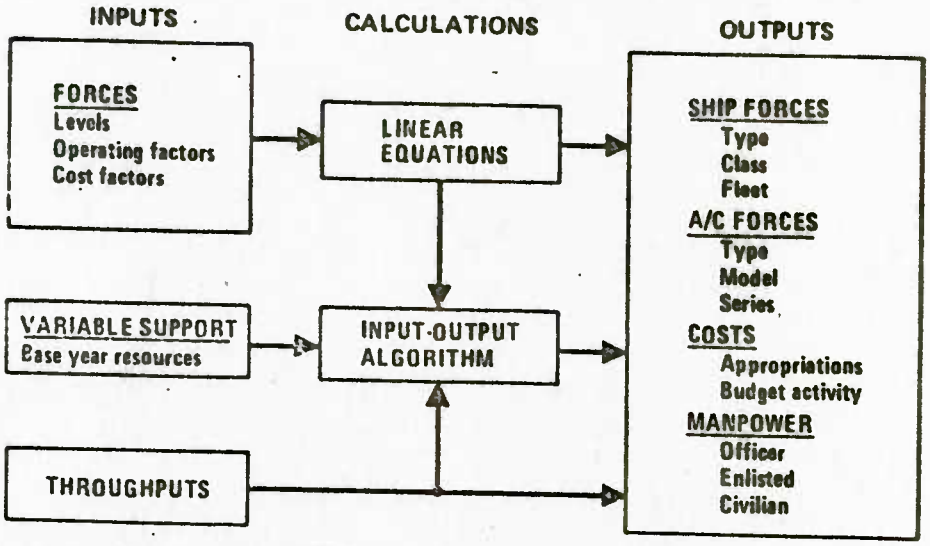
PREFACE

This view of the Navy Resource Model (NARM) is intended for the reader who is not already familiar with the NARM and wants to gain a general understanding of how it works. The reader who wants a more detailed understanding should refer to the comprehensive bibliographies in the two Navy Resource Study progress reports, "Navy Resource Study Progress Report and Proposed Program," J. Augusta, (INS)1188-72, 15 August 1972, and "Navy Resource Study Progress Report and Proposed Program," H. Kanter, (NWG)193-71, 3 August 1971. They, and the papers listed in their bibliographies, are available upon request.

The present writing draws upon the work of a number of people from the Resource Analysis Division (RAD) of CNA and staff members of Op-904. It also borrows liberally from material presented at briefings by Herschel Kanter and Joseph Augusta of CNA.



THE NAVY RESOURCE MODEL

Since 1969 the services have been required to develop their preferred programs within a fiscal constraint set by the Secretary of Defense. Today's Navy planner chooses force levels, major procurement programs, and ship and aircraft operating policies; constrained by the fixed budget, he achieves increases in one area only by giving up resources in another. It became desirable to have an automated technique that would rapidly and consistently determine the resources needed for the many broad choices open to Navy decision-makers within fiscal guidance. The Center for Naval Analyses developed the Navy Resource Model (NARM) for this purpose. Given data that describes a base year, and a force structure of ships and aircraft that is desired in future years, it will develop a consistent program for those years.

The model calculates ship and aircraft operating costs and manpower (direct) and the related support operating costs and manpower (indirect). Of support resources, only those in the "general support" fiscal guidance categories that vary with the size or operating policies of the forces are estimated. Direct and support resources not estimated are throughputs, i.e., their output values are equal to their input values. Throughputs are included in the model for the sake of completeness; the model therefore contains data for all Department of the Navy resources–appropriations, manpower, ships and aircraft. Table 1 shows what part of these resources is estimated by the model. Roughly three-fourths of the operating dollars (MPN and O&MN) and about two-thirds of all manpower (military and civilian) are covered.

Different techniques are used to calculate direct and support resources. By means of linear equations derived from previous or current spending patterns the model first estimates the men and dollars needed to operate the given forces. These resources become proxy measures of the support establishment's workload, or output. The model then estimates the support resources needed to produce that output by first calculating the ratio of support resources (input) to output in a base year and then applying it to the new output. The next sections describe these calculations in more detail.

TABLE 1

RESOURCES ESTIMATED BY NARM

	Percentage of FY 72 Budget			
	Aircraft and Ship Direct Factors	Variable General Support	Total Percent Estimated	Throughputs
Appropriation				
Operating				
MPN	41	35	76	24
O&MN	35	33	68	32
Procurement				
OPN				100
PAMN	5		5	95
SCN				100
Other				
MILCON				100
RDT&E				100
Marine Corps				100
Naval Reserve				100
Personnel				
Navy Officers, active duty	31	33	64	36
Navy Enlisted, active duty	51	31	82	18
Civilians		49	49	51
Marine Corps				100
Reserve				100

Ship and Aircraft Direct Resources

The model computes the operating cost and manpower for each ship class and aircraft series and sums them to arrive at the total direct operating cost and manpower. The linear equations used to compute manpower and MPN are illustrated in exhibit 1 for the DE-1040 class in the Atlantic Fleet. End strength is computed by multiplying the number of ships in the class by the allowance per ship. As exhibit 1 shows, average strength in a year is computed as the mean of the end strengths for that year and the previous year. MPN is then computed as a function of average strength.

A detailed list of the variables that are used in deriving the operating costs is shown in exhibit 2. For example, aircraft O&MN is composed of the costs of flight operations, engine overhaul, component reworks and airframe reworks. These are dependent upon the input variables listed; e.g., the cost of flight operations varies with flying hours per month and costs per flying hour. The user may change the value of any of these variables and compute what that change means for operating costs.

A change in direct resources will also affect the support establishment. The NARM thus proceeds to estimate the support resources associated with that change. This calculation is discussed next.

EXHIBIT I

ILLUSTRATION OF MANPOWER AND MPN COMPUTATION FOR DE-1040 CLASS IN ATLANTIC FLEET

Factors

[Factors are not actual and are for illustrative purposes only]

	FY 74	FY 75
Number of ships	10	8
Enlisted allowance per ship	225	230
Officer allowance per ship	17	18
Average enlisted pay	$ 7,360	$ 7,360
Average officer pay	$16,869	$16,869

End Strength Computation for FY 74

Enlisted = 10 x 225 = 2,250
Officer = 10 x 17 = 170

End Strength Computation for FY 75

Enlisted = 8 x 230 = 1,840
Officer = 8 x 18 = 144

MPN Computation for FY 75

$$\text{Average enlisted strength} = \frac{2250 + 1840}{2} = 2045$$

$$\text{Average officer strength} = \frac{170 + 144}{2} = 157$$

Enlisted MPN = $7,360 x 2,045 = $15.05 million
Officer MPN = $16,869 x 157 = $2.65 million
MPN = $15.05 + $2.65 = $17.7 million

EXHIBIT 2

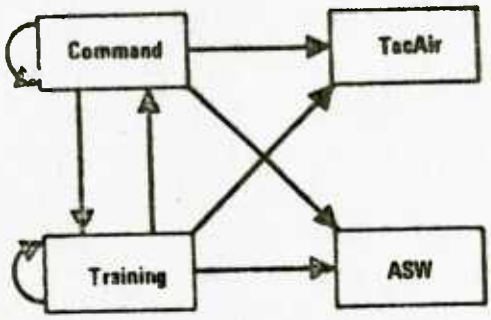
FACTORS USED IN COMPUTATION OF DIRECT COSTS OF SHIPS AND AIRCRAFT

I. Ships (for each class, e.g., DE-1052, SSN-688)
  A. MPN
    1. Officers per ship
    2. Enlisted per ship
    3. Average pay per officer and enlisted
  B. O&MN
    1. Overhaul costs
      a. Cost per overhaul
      b. Overhaul interval
      c. Overhaul duration
    2. Conventional fuel
      a. Steaming hours underway
      b. Barrels of fuel per steaming hour
      c. Steaming hours not underway
      d. Barrels of fuel per steaming hour not underway
      e. Cost per barrel of fuel
    3. Utilities
    4. Restricted availability
    5. Repair parts consumption
    6. Tender availability
    7. Other ship O&MN
    8. Fleet TAD

II. Aircraft (for each series, e.g., F-4B, A6-A)
  A. MPN
    1. Officers per aircraft
    2. Enlisted per aircraft
    3. Average pay per officer and enlisted
  B. O&MN
    1. Flight operations
      a. Cost per flying hour
      b. Flying hours per month
    2. Engine overhaul
      a. Cost per flying hour
      b. Flying hours per month
    3. Component reworks
      a. Cost per flying hour
      b. Flying hours per month
    4. Airframe reworks
      a. Time between reworks
      b. Time in rework
      c. Cost per rework
  C. PAMN: Replenishment spares
      a. Cost per flying hour
      b. Flying hours per month

Support Resources

Input-output analysis functionally relates the support establishment to the forces supported and accounts for support-on-support. Support-on-support refers to the support given by the support establishment to itself. Each support organization supports not only the operating forces, but also itself and other support organizations. This concept is illustrated in the diagram. The command and training organizations support themselves, each other, and the operating forces. Increased demand for training support from TACAIR increases the training workload; this increase causes the training unit to demand more support from the command unit, which increases the command workload and its demands on training. These reverberations, which are infinite in number but become increasingly smaller in size, are captured by the input-output technique.



To use input-output analysis, we divide the Navy into "sectors" representing organizations or functions such as Recruit Training and Anti-Submarine Warfare Forces. These sectors are divided into two groups: those that support other sectors, and those that do not. The support establishment is contained in the first group, called "support," and the forces are contained in the second group, called "final users." The model makes a further distinction within the group of support sectors according to whether or not the support sector varies with the forces. The ones that do not are placed in the final user category and thus the "support" group includes only variable support sectors. (Examples of support activities that are held fixed with respect to force changes are the Naval Academy and Washington-level headquarters.)

The model does not attempt to measure the actual support provided to users by support sectors. Rather it uses proxies for the real output. The proxy variables are characteristics of the users. For convenience, the particular characteristics used are the operating costs or manpower. The real output of a sector is assumed to vary in proportion to its proxy. In Recruit Training, for example, actual output is trained recruits; the proxy variable used is the number of enlisted men in each sector. The rationale is that on the average, the number of trained recruits required by each sector will vary in proportion to the number of men in that sector.

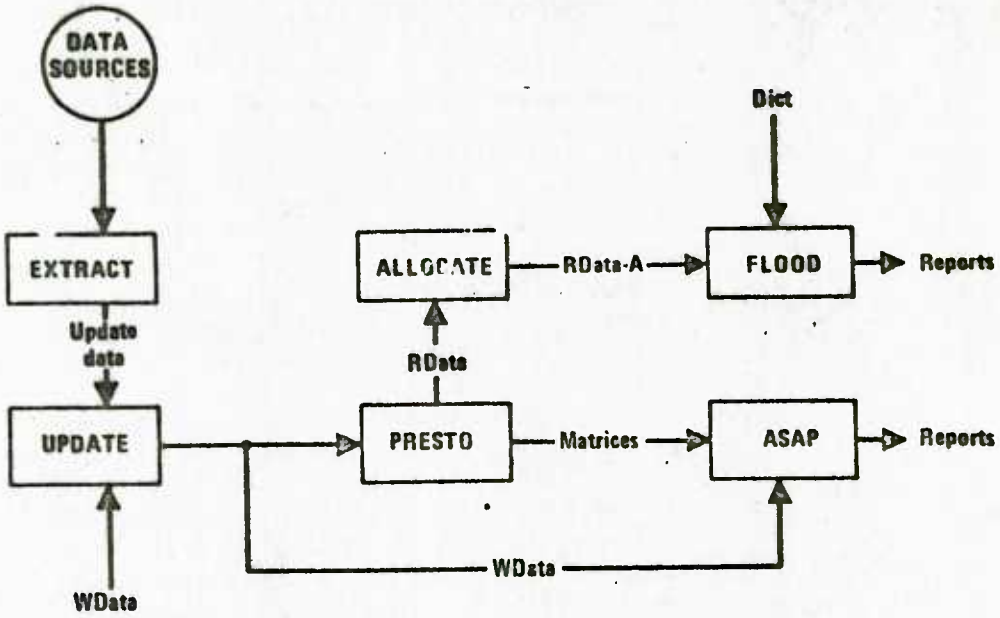
Data describing the support output in a base year is organized into a transactions matrix. The structure of the matrix can be illustrated by a rearrangement of the simple diagram above and the addition of resources from outside.

	Command	Training	TacAir	ASW	Total
Command	815	1542	2920	3280	8557
Training	328	64	406	665	2263
O&MN	456	259	286	367	
MPN	328	864	406	665	

The rows of the upper quadrants represent the flow of support from support sectors to both support sectors and final users. The quantities represent the magnitudes of the arrows in the diagram. The columns of the lower left quadrant are the resources that must be inputted to the support sectors for them to generate their total outputs. In this case, the Command support sector needs 456 units of O&MN and 328 units of MPN to produce its total output of 8557 units. This tableau relates the input and output, implicitly reflecting the support relationships in the data. The input-output technique projects these same support relationships for any set of final users, estimating the resources needed by the support establishment to maintain the relationships.

The support resources vary linearly with the support activities' workload so that a change in workload, whether caused by a force change or support reduction, results directly in a change in support resource requirements. The model does not allow for tradeoffs between resources or program elements within a support sector, so that different resources within a sector are distributed similarly in all years.

Note. The NARM divides the Navy into 37 support sectors and approximately 1500 final users (each aircraft series and ship class is a final user). Each may be composed of one or more program elements.



THE COMPUTERIZED SYSTEM

Although the NARM is a single model, its functions are interpreted through six computer programs. Data files created by programs EXTRACT and UPDATE become input to the computational programs, PRESTO and ALLOCAT. Computed results as well as input data are reported to the user, in the format desired, by program FLOOD (the report generator). When the marginal effects of limited force changes are wanted quickly and directly, they are computed and reported by ASAP.

The processing begins with the construction of a master input data file, the WDATA tape. This "working" data is broadly classified into four categories—ships, aircraft, variable support, and throughputs—and is further identified by ship class, aircraft series, support sector, or appropriation or type of personnel, and by fiscal guidance category, program element, claimant, year, and factor, as applicable to the specific data element concerned.

The tape contains data derived from budgeting documents, the fleets, NavAir, NavShips, the Navy Cost Information System, the Ships Planning System, Op-05 and the Aircraft Program Data File.[1] Because these sources frequently update their files, the data input routine was automated to facilitate maintaining a current data base. The General Extract Program serves this function by extracting update data from tapes received from the data sources. It creates a new data file, sorts the data, merges equivalent records, and produces an output tape which becomes input for program UPDATE.

UPDATE maintains and updates the WDATA file by changing the old WDATA file in accordance with the GEP output tape or punched card instructions. Alterations include adding data to the file, replacing data on the file, changing the data elements either absolutely or algebraically, deleting portions

[1] Thus, the direct and support resources in the base year are consistent with the proposed budget.

of the file, and multiplying data by adjustment factors. The output tape is a new WDATA master file of input data to be used by PRESTO.

PRESTO contains the estimating techniques described in the preceding section. The program first calculates the operating resources required by each ship and aircraft. Next, from the support input data for a base year and the results of the ship and aircraft computations, the input-output technique computes the total support resources. After these computations are completed, PRESTO creates a data file, RDATA ("results" data), which may be input into ALLOCAT or directly into the report generator. (PRESTO also produces a tape containing the support matrices to be used as input for programs ASAP and ALLOCAT or for later runs of PRESTO.)

ALLOCAT computes the support allocated to each final user and adds this information to the RDATA file, creating an RDATA-A file. The resulting RDATA-A tape provides detailed force and support data for input to program FLOOD.

FLOOD is the primary program used to produce reports in the NARM. It uses the WDATA, RDATA or RDATA-A file as input and produces reports displaying the data at the level of detail and in the arrangement selected by the user. The user may choose from more than 100 data items and the data selected may be displayed in over 360,000 formats. This versatility allows reports to be tailored to suit any particular analysis; for example, for details, the user would request POM-type reports, whereas for summary data he would request a SNAP type.

The PRESTO-FLOOD combination has been used in most analyses and in responding to most questions. On the other hand, ASAP also computes and reports the effects of changes in force structures or direct factors on Navy resources. But whereas FLOOD reports the total Navy resource requirements, ASAP reports the *marginal* changes in them (that result from a change in force level or operating factor) and accounts for only the forces and variable support, ignoring throughputs. Also, ASAP does not have the report generating capacity of FLOOD, but instead prints out several standard reports.

To run ASAP, the user inputs force or operating factor changes; the program then alters the force levels or factors on the WDATA tape in accordance with this input. Using the altered WDATA tape together with the support matrix tape generated by PRESTO, ASAP then computes its results and reports them to the user.

NARM-Related Programs

Several other programs interact with the NARM, although they are not part of the main system. The principal ones are SHOPM, AFPM, Outlay 20 and COMPRESS.

SHOPM (Ship Overhaul Projection Model) projects overhaul schedules for each ship in the active fleet by fiscal year, and provides a total for each ship class as well as a grand total. It also provides a list of ships to be overhauled in each year. The projections are based on (1) the last date each ship actually began a regular overhaul, (2) the date the ship is currently scheduled to enter the active fleet, (3) the overhaul cycle (sum of duration and interval) currently stipulated for each ship or class of ships, and (4) the year the ship is scheduled

to leave the active fleet. The General Extract Program may be used to extract the overhaul data from SHOPM's output for input to the NARM's WDATA tape.

AFPM (Aircraft Force Projection Model) projects the Navy's aircraft inventory over a 10-year period, adjusts it to the operating requirements of a given set of forces, and reports out the adjusted inventory. The projections account for service life, maintenance time, non-combat attrition, new procurement, and conversion. AFPM will also compute average age of aircraft and calculate the effect on it of alternative aircraft procurement policies. In balancing inventory and force levels, the model will search for alternative ways to approach the requirements. The options considered are to use the aircraft beyond normal service life; to increase aircraft procurement; to reduce the pipeline requirements; or to use alternative series (F-4B instead of F-4J). Aircraft forces in the NARM are used as input to AFPM (or vice versa). The output of AFPM can take the form of cards for changing those forces in the NARM.

Program Outlay 20 converts obligational authority into outlays for the 14 Department of the Navy appropriation categories. The user has the option of specifying the percentage of the procurement TOA (PAMN, SCN, OPN, and PMC) to be expended. The factors for each year are printed in a table on the first page of output. On each subsequent page, two tables are printed. The first table contains a summary of the obligational authority input data. The second table contains the results calculated by this program: the outlay stream over a period of years for each appropriation category. This table also contains the Navy and Marine Corps sub-totals, a wedge (outlay requirements from earlier years' obligations) and adjustments (changes necessary in some cases to achieve required totals).

COMPRESS (Computer Operated Model for Phased Resource Estimation of Strategic Systems) estimates the costs of missile systems by function (offensive or defensive) and of platforms by type (fixed or mobile, land or sea based). Output includes static 10-year systems costs by missile and platform, and time-phased costs. COMPRESS estimating relationships have been derived from a variety of sources and stress relative accuracy in the costs of alternative systems, requiring only information usually available in the early conceptual stages of system definition.

AFTERWORD ON THE USES OF NARM

In the past the model has been used for–

Developing costs of force alternatives.
Developing costs of support alternatives.
Developing MPN and O&MN appropriation controls through estimating appropriate funding for chosen forces and operating policies.
Estimating airframe reworks and ship overhauls.
Estimating the effect of force changes on the support establishment.
Comparing NARM estimates with OSD support estimates.
Developing POM-73 and POM-74.
Estimating the effects on direct cost and support of a change in ship allowance.

Because it contains all the Navy's resources it has also been a valuable information retrieval system.

While it currently possesses the features needed to provide assistance in developing Navy documents and answering questions, it is being developed further. CNA devotes continuing effort to improving the data base and estimates, increasing the coverage of the estimates and the detail of the data, creating a responsive, dynamic model. In general, we tailor the model to the Navy's needs by restructuring it to address questions in the detail useful to the Navy decision-makers.